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FINAL TECHNICAL REPORT

NASA Grant NAGW-44

"The Nature of Dwarf Novae and Related Systems"

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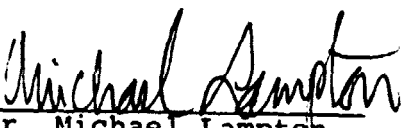
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January 27, 1983

### Final Report on NASA Grant NAGW-44

NASA grant NAGW-44 was awarded in order to further our understanding of the high energy emissions from cataclysmic variables (interacting binary systems containing an accreting white dwarf) and to study the relationship of the high energy emission of these stars to their optical properties. A subsidiary aim was to examine the relationship of the cataclysmic binaries to the strong X-ray emitting binaries that contain a neutron star as accreting star.

The research done under this grant has resulted in a number of publications as listed at the end of the report. The following is a brief summary.

A soft X-ray survey of cataclysmic variable stars has been carried out using the Einstein observatory. Approximately 75% of all the sources observed were detected in short (2000 sec) observations. Relationships between the X-ray and optical luminosity and the dependence of this quantity on the subclass of the variable have been investigated and have provided constraints on the nature of these systems. The results have been reported by Cordova, Mason and Nelson (1981), and Cordova and Mason (1981 and 1982). A final paper which includes information on the variability of the sources is almost complete (Cordova and Mason 1982).

Still on the subject of X-ray observations, HEAO-1 soft X-ray pointed data on the cataclysmic variables U Gem and SS Cyg during outburst have been analysed. These two dwarf nova are, so far, the only members of their subclass which have been found to show an intense ultra-soft X-ray emission component during outburst. In both cases the emission exhibits quasi-periodic pulsations, with periods of order 25s and 9s for U Gem and

SS Cyg respectively. The observational properties of this emission have been defined and mathematical models of the pulsations constructed.

Optical observations have been conducted of cataclysmic variables and related close binary X-ray sources. A previously uncatalogued dwarf nova, E1551+718, has been identified with an X-ray source observed serendipitously in the same field as another target and is reported by Mason et al (1982). A number of HEAO-1 soft X-ray sources have been surveyed with the Einstein detectors in order to reduce their positional uncertainties. Two of these have been optically identified with new variables of the AM Her class (only four of these were known previously). A paper discussing the identification, optical spectrum and optical time variability of one of these sources, E1405-451, has been submitted for publication (Mason et al 1982). A paper on the second, E1013-477, is in preparation. High time resolution optical photometry of the X-ray pulsar 4U 1626-67 has revealed the orbital period of the system to be 40 minutes. This is the shortest orbital period known in this class of star (Middleditch et al 1981). An optical burst, lasting ~20 seconds, has been observed from the X-ray source 4U 1254-69 which was not previously known to be a burster (Mason et al. 1980). This is the first time that a burst source has been catalogued in the optical region of the spectrum.

Ultraviolet, optical and infrared photometry and time resolved optical spectroscopy has been obtained of the X-ray source 2A 1822-371, which was discovered to be a 5.57 hour binary system (Mason et al 1980, Mason and Cordova 1982a, Mason et al 1982 and Mason and Cordova 1982b). The ultraviolet observations were made with the IUE satellite and the infrared observations with the NASA IRTF telescope on Mauna Kea. 2A 1822-371 has

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proved to be an extremely important system for furthering our understanding of the structure of accretion disks around X-ray binaries and cataclysmic variables and the relationship between these two types of objects. The light curve of the star varies as a complex function of energy. Evidence is presented for a bulge on the outer edge of a luminous X-ray heated accretion disk caused by the impact of the mass transfer stream from the companion. The complexity of the ultraviolet, optical and infrared light curve is found to be due to the fact that the modulation is made up of four components - occultation of the luminous disk by the bulge, the changing aspect of the X-ray heated inner face of the bulge, the changing aspect of the cooler outer face of the bulge and the changing aspect of the X-ray heated face of the companion (mass donating) star. Such a model fits the data extremely well when model parameters are used that are consistent with the X-ray light curve. This source provides the best measurement so far obtained of the vertical structure of an accretion disk. The model also provides a distance estimate of about 2.5 kpc for the star.

IUE ultraviolet observations have also been made of a number of cataclysmic variables. Evidence of a high velocity wind has been discovered in the dwarf nova TW Vir during its optical outburst state, in the form of a marked P Cygni profile in the CIV 1549 line (Cordova and Mason 1982). Observations of the eclipsing system RW Tri have also been obtained which are consistent with this idea. It was found that the ultraviolet line emission of this star did not diminish during the eclipse of the continuum, indicating that the lines come from a large extended source. Time resolved ultraviolet spectrophotometry has also been obtained on the pulsating cataclysmic variable H2252-035. No modulation corresponding to the 3 hour

optical orbital modulation was found in the ultraviolet light, constraining the temperature of the modulated source. Evidence was found, however, for orbital modulation of the ultraviolet emission lines. The data also provide the first accurate measurement of the overall spectrum of this important source.

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Publications

- 1 A 5.57 hour modulation in the optical counterpart of 2S 1822-371 (K.O.Mason, J.Middleditch, J.Nelson, N.White, P.Seitzer, I.Tuohy and L.K.Hunt) 1980, Ap.J. 242, L109.
- 2 4U 1626-67: A prograde spinning X-ray pulsar in a 2500s binary system (J.Middleditch, K.O.Mason, J.Nelson and N.White) 1981, Ap.J. 244, 1001.
- 3 An optical burst from the star associated with 2S 1254-690 (K.O.Mason, J.Middleditch, J.Nelson and N.White) 1980, Nature 287, 516.
- 4 A soft X-ray halo around SU UMa (F.A.Cordova and K.O.Mason ) 1980, Nature 287, 25.
- 5 A soft X-ray survey of selected cataclysmic variable stars with the Einstein observatory (F.A.Cordova, K.O.Mason and J.E.Nelson) 1981 Ap.J. 245, 609.
- 6 Pointed soft X-ray observations of AM Herculis from HEAO-1 (I.R.Tuohy, K.O.Mason, F.Lamb and G.Garmire) 1981 Ap.J. 245, 183.
- 7 Identification of the X-ray source E 1551+718 with an uncatalogued dwarf nova (K.O.Mason, G.A.Reichert, S.Bowyer and J.Thorstensen) 1982 PASP (in press)
- 8 Ultraviolet spectrophotometry of 2A 1822-371: A bulge on the accretion disk (K.O.Mason and F.A.Cordova) 1982 Ap.J. 255, 603.
- 9 Phase resolved optical spectroscopy of the compact X-ray binary 2A 1822-371 (K.O.Mason, P.G.Murdin, I.R.Tuohy, P.Seitzer and G.Branduardi-Raymont) 1982, MNRAS 200, 793.
- 10 Optical identification of the X-ray source E1405-451: a 101.5 minute binary system with extremely rapid quasi-periodic variability (K.O.Mason, J.Middleditch, F.A.Cordova, K.A.Jensen, G.Reichert, P.G.Murdin, D.Clark and S.Bowyer) 1983 Ap.J. 264 (in press).
- 11 Infrared photometry of the X-ray binary 2A 1822-371: A model for the Ultraviolet, Optical and Infrared light curve. (K.O.Mason and F.A.Cordova) 1982, Ap.J. 262 (in press).
- 12 High velocity winds from the accretion disk of a dwarf nova in outburst (F.A.Cordova and K.O.Mason) 1982 Ap.J. 260, 716.
- 13 Ultraviolet observations of the X-ray binary pulsar H2252-035 ( F.A.Cordova, E.Fenimore , J. Middleditch and K.O.Mason) 1982 Ap.J. 265 (in press).

- 14 Observations of quasi-coherent soft X-ray oscillations in U Geminorum and SS Cygni (F.A.Cordova, T.J.Chester, K.O.Mason, S.M.Kahn and G.P.Garmire 1983 Ap.J. (in press).
- 15 X-ray observations of a large sample of cataclysmic variables stars using the Einstein X-ray observatory (F.A.Cordova and K.O.Mason) 1983 Ap.J. (to be submitted).
- 16 Accreting degenerate dwarfs in close binary systems (F.A.Cordova and K.O.Mason) in Accretion driven stellar X-ray sources ed. W.H.G.Lewin and E.P.J.van den Heuvel, Cambridge University Press, Cambridge, England (1982).
- 17 Cataclysmic variable stars from X-ray to infrared wavelengths: Recent results on the continuum distribution (F.A.Cordova and K.O.Mason) IAU Commission No.27 on variable stars, ed. D.Fernie (1982).

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